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Microplastics in Inland Saline Lakes of the Central Ebro Basin, NE Spain

Katia Hueso-Kortekaas [1,2,3], Noemí Delgado-Mellado [1,2], Javier Calzada-Funes [1,2], Carlos Sanchez-Mata [1], Carmen Castañeda [4] and María del Mar Cledera-Castro [1,2,5,*]

[1] ICAI School of Engineering, Universidad Pontificia Comillas, Alberto Aguilera, 25, 28015 Madrid, Spain; khueso@comillas.edu (K.H.-K.); ndmellado@comillas.edu (N.D.-M.); jcalzada@comillas.edu (J.C.-F.)
[2] Group on Emerging Pollutants and Resource Recovery, Universidad Pontificia Comillas, Alberto Aguilera, 25, 28015 Madrid, Spain
[3] IPAISAL Network, Apartado de Correos 50, 28450 Collado Mediano, Madrid, Spain
[4] Estación Experimental de Aula Dei, EEAD-CSIC, Avenue Montañana 1005, 50059 Zaragoza, Spain; ccastaneda@eead.csic.es
[5] Institute for Research in Technology, ICAI, Universidad Pontificia Comillas, Alberto Aguilera, 25, 28015 Madrid, Spain
* Correspondence: mcledera@comillas.edu

Abstract: Saline lakes are rare and fragile habitats with a high conservation and scientific interest. We have studied the presence of microplastics (MPs) in the water of four inland saline lakes located in the Central Ebro Basin (CEB), NE Spain. Quantification and characterization of MPs were performed by optical microscopy and micro-Fourier Transform Infrared Spectroscopy (micro-FTIR). MPs analyzed covered the 5–5000 µm range. Most of the MPs collected were contained in the 250–500 and 500–1000 µm ranges. The concentration of MPs varied from 850 ± 271 to 1556 ± 59 MPs/L, fibers being the most dominant typology. Seven different colors were observed, the most abundant being black, and seven types of plastic were identified, polyester, polyethylene terephthalate, and nylon the most abundant. The smallest lakes presented a more homogeneous MP size distribution and a wider variety in color and polymer composition. This work shows that the MP concentration in these lakes is at least one order of magnitude higher than previous values reported in similar environments, and it is expected to multiply fast. This highlights the importance of the hydrological characteristics of these lakes, the evapotranspiration being the only water outflow, the atmospheric deposition of MPs, and other anthropogenic causes.

Keywords: microplastics; saline lakes; wetlands; micro-FTIR

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Academic Editor: Jian Liu

Received: 5 March 2025
Revised: 25 March 2025
Accepted: 26 March 2025
Published: 28 March 2025

Citation: Hueso-Kortekaas, K.; Delgado-Mellado, N.; Calzada-Funes, J.; Sanchez-Mata, C.; Castañeda, C.; Cledera-Castro, M.d.M. Microplastics in Inland Saline Lakes of the Central Ebro Basin, NE Spain. *Water* **2025**, *17*, 989. https://doi.org/10.3390/w17070989

1. Introduction

Despite covering half of the world's inland waters and being found across the world [1,2], salt lakes and other natural saline wetlands are rare and fragile habitats. They host endemic species of flora and fauna that are especially vulnerable to environmental change due to the need to adapt to high salinity, high UV radiation, low dissolved oxygen, and irregular cycles of drought and inundation. The trophic networks are relatively simple, as few organisms can cope with such harsh environmental conditions [3,4], and these have a narrow ecological niche, increasing their vulnerability. Minor changes in any of these factors can be a risk to ecosystem well-being and function.

Saline wetlands have often been overlooked by science [5], as they cannot contribute to the provision of freshwater and fish (in the case of hypersaline systems) and have, therefore, less obvious value. However, given the rarity and the fragility of these ecosystems and the halophilic organisms that inhabit them, saline wetlands are of high scientific and conservation interest. The physiological adaptations needed to cope with the environmental conditions may provide clues for how life can develop in extreme conditions, such as extraterrestrial habitats [6,7]. Also, they constitute important stopover and breeding sites for migratory birds. These wetlands also play an important role in regional hydrology, having a close connection with hypersaline aquifers and the rest of their catchment [8,9]. In the past, some of these lakes were used to harvest salt, water, and mud for therapeutic and well-being purposes. They also constitute visually striking landscapes, featuring bodies of water with a brim of salt crust and surrounded by vast drylands. Hence, saline wetlands provide essential ecosystem services, such as provision (minerals, muds), regulation (flood control, nutrient cycling), support (of vulnerable biodiversity), and cultural (esthetic values, artistic inspiration, local identity) [10].

Most inland saline wetlands are located in arid and semiarid areas of the world, concentrating in the western region of the Americas, central Asia, parts of Africa, and Australia [2,11]. Spain is one of the only European regions harboring a significant abundance of this type of habitat and can, therefore, be considered unique at a continental scale [12]. Within Spain, the areas that concentrate most natural inland saline wetlands are the Ebro Basin (Figure 1) in the northeast, La Mancha in the south-central area of the Iberian Peninsula, and a few others in the regions of Andalusia, Castilla y León, and Murcia. In this paper, the fluctuating hypersaline wetlands of two Ramsar sites, the "Saladas de Bujaraloz-Sástago" (the *saladas* hereinafter) and Gallocanta Lake, will be addressed together with the actually permanent and less saline Sariñena Lake (Figure 1A), anthropized by intensive agriculture from decades. Gallocanta Lake (Figure 1B) is the largest saline lake in Europe.

The CEB is one of the most arid regions in Europe, with a BSk Köppen cold semiarid climate type [13]. The *saladas* are located at 310–370 m a.s.l. with over one hundred and a half playa-lakes and closed depressions of aeolian and karstic origin, small in size, shallow, and many of them temporary or even ephemeral [14]. Here, we sampled Salineta and Pito playa-lakes. The municipalities of Bujaraloz (Salineta Lake) and Sástago (Pito) have a population density of 8.29 and 3.09 inhabitants per square kilometer, respectively, therefore considered a "very low density" area according to the EU NUTS classification system, also popularly known as a "demographic desert". The main human activities in the CEB traditionally are extensive and irrigation agriculture, the first around Gallocanta Lake, Salineta, and Pito playa-lakes, and the second around Sariñena Lake. Between 1988 and 2003, 50% of the *saladas* have disappeared [6]. The remaining ones suffer different threats, such as reclamation for agricultural or industrial purposes, dumping of stones from the clearing of nearby agricultural fields, eutrophication from fertilizer and other agrochemicals, and modification of the natural hydrological regime due to irrigation return flows. In the 21st century, new industrial activities in the region, such as large porcine farms and photovoltaic solar farms, affect the water quality, biodiversity, and the landscape of these wetlands [14]. Many of these threats are shared with saline lakes elsewhere in the world [2,5]. Gallocanta Lake, on the other hand, is also a temporary endorheic lake. It is located at 992 m a.s.l. presents a maximum length of 7 km and a maximum width of 2 km, which makes it the largest natural saline lake in the Iberian Peninsula. In spite of its protected status and its fame among birdwatchers, the lake suffers eutrophication despite the water level decrease in recent decades [15].

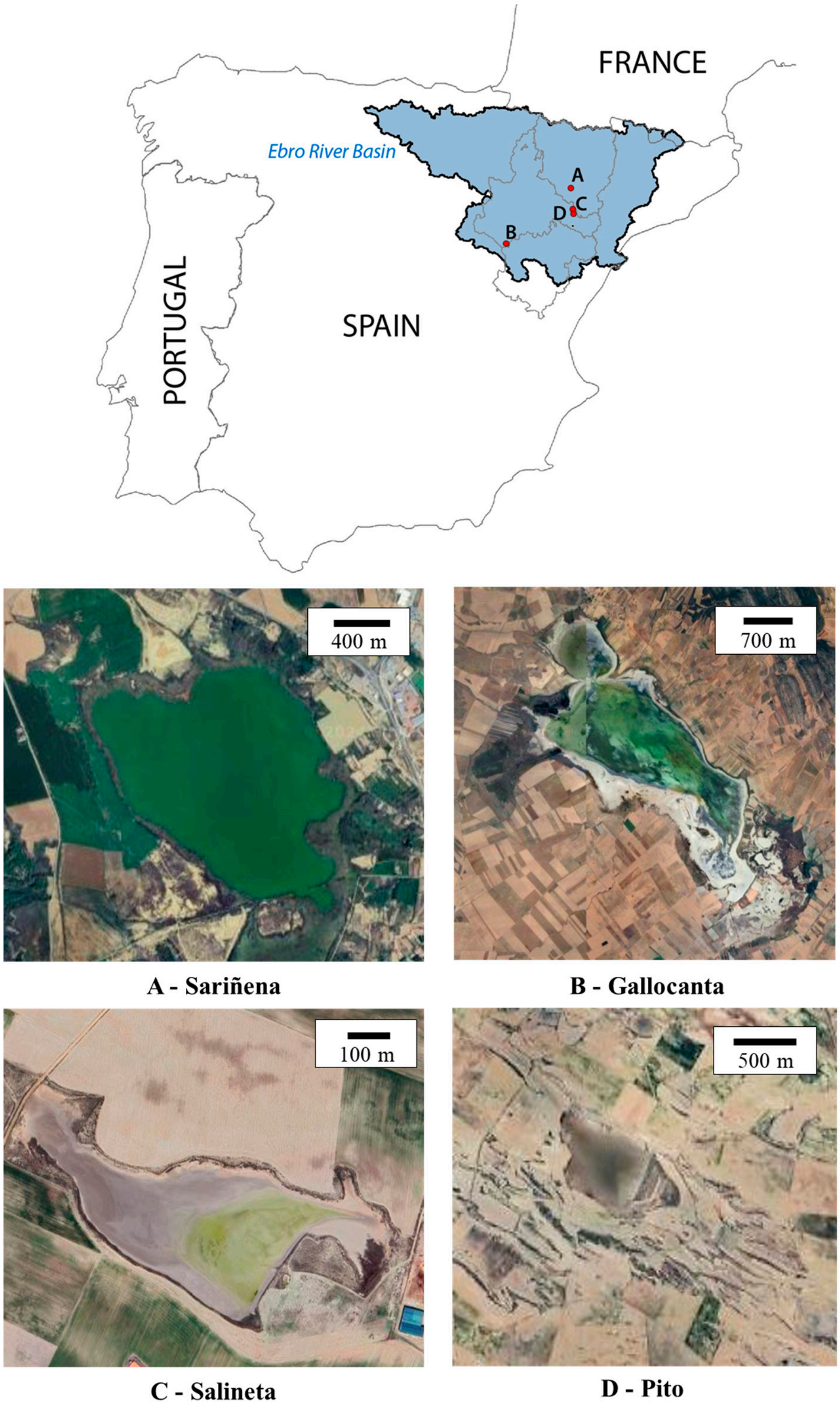


Figure 1. Location of the sampling sites in the Spanish provinces and orthophotographs (**A**–**D**) from Google Maps (September 2024) showing the lakes. In blue is the Ebro River Basin.

Pollutants of emerging concern are one of the most recent and ubiquitous threats, notably microplastics (MPs) [16]. Lakes and reservoirs are especially vulnerable environments to MP pollution, as they tend to accumulate it in their basins. Nava et al. [17] studied 38 lakes and reservoirs across the world and observed that the most polluted ones showed concentrations exceeding those found in the infamous ocean gyres that were reported already in 1990, then named "garbage patches" [18]. MPs in saline lakes and lagoons are understudied–they were not included in Nava et al.'s comprehensive study of inland waters [17], and their abundance, fate, and effects are yet to be understood. Although it is not proven that current environmental concentrations induce toxicity, MPs may disturb habitats by reducing the available nutrients, inhibiting primary consumers, or acting as a substrate for the dispersal of toxins, trace metals, pathogens, or invasive species. MPs may cross bodily barriers and translocate between organs, being a threat to the health of plants and animals [19–23]. Salinity creates unique conditions that may affect the behavior of MPs or accelerate their rate of degradation by photooxidation, which can further reduce the MPs in size, increasing the risk of uptake and retention by the environment and its biota. This is further aggravated by the high UV radiation and low dissolved oxygen found in these wetlands. The presence of contaminated water may exacerbate the pollution by MPs, as it further accelerates their degradation and dispersal [24].

Dispersal of MPs into lakes and lagoons located in rural areas or natural habitats typically occurs via surface runoff and discharge from farms, small industries, or isolated settlements. In certain cases, MPs may be transported by migratory birds through ingestion and subsequent regurgitation of defecation or adhered to their legs [25,26]. There is growing evidence that lakes of various dimensions in remote regions, such as saline lakes found worldwide, contain striking abundances of MPs, hinting at airborne dispersal [27–29]. Atmospheric fallout of MPs has been proven in inland *salinas* in Spain [30]. In Spain, MPs have been detected in the sediments of the saline lakes of La Mancha Húmeda UNESCO Biosphere Reserve [31]. In this exploratory work, MPs coming from both surface runoff and atmospheric fallout are expected to be found in several inland saline lakes of the CEB in NE, Spain.

Abundances and morphological characteristics of MPs have been documented in lakes worldwide [28,32–36]. Fibers and fragments are the most common typologies of MPs found [37]. The main polymers that are contaminated are polypropylene (PP) and polyethylene (PE) for sediment and water, while PE and polyethylene terephthalate (PET) are mainly found in biota. Films are the dominant MP typology in non-artificially recharged lakes [31]. In general, lakes are regarded as sinks for MPs [28], even more so in the case of endorheic basins where the input of water and sediments predominates, leading to the accumulation of MPs [31]. Among aquatic environments, inland saline wetlands are underrepresented in the research of MP pollution, having found studies in China (Qinghai, Geren Co, Wuru Co, Mujiu Co, and Siling Co lakes), Iran (Maharloo Lake), India (Pangong, Tsomoriri, and Tsokar Lakes) or Argentina (La Salada lake) [24,38–41]. Most authors also agree that the effect of MPs, especially in saline environments, is yet understudied [24,42]. The above-mentioned conditions, given the fragility of these ecosystems, constitute an issue of growing concern.

2. Materials and Methods

2.1. Location

The selected saline lakes are located in Huesca, Zaragoza, and Teruel provinces in the CEB, NE Spain. Samples of water were obtained from four saline lakes. They represent a gradient of salinity and a diversity of saline environments, from small, shallow lakes to deeper and/or bigger lakes [12,43]. Salineta (23 ha [43]) and Pito (80.5 ha [43]) are smaller and hosted in close depressions of aeolian and karstic origin; Gallocanta Lake (1450 ha [15]) and Sariñena Lake (137.7 ha [44]) are bigger. Gallocanta Lake is fluctuating while Sariñena Lake is now permanent after receiving agricultural return flows from nearby irrigation for decades. All the wetlands studied are slightly lower than the surrounding terrain, are located at low-lying positions in their watersheds with a gradient of gentle slopes, and are frequently windswept areas. Figure 1 shows the location of the sampling sites, and Table 1 includes their main characteristics.

Table 1. Main characteristics of the lakes sampled.

ID	Lake	Latitude	Longitude	Hydric Regime	Surface Extent (ha)	Electrical Conductivity ** (dS/m)
A	Sariñena	41.797720	−0.180270	Permanent	137.7	2.45
B	Gallocanta	40.971938	−1.501162	Fluctuating	1450.0 *	47.30
C	Salineta	41.482195	−0.160151	Highly fluctuating	23.0 *	79.40
D	Pito	41.412354	−0.151142	Highly fluctuating	80.5 *	27.10

* Surface area extent corresponding to the maximum extension of the inundable lakebed. ** Measured during the sampling campaign, December 2022.

Water inflows and outflows determine the water level and variable salinity of the fluctuating saline lakes. Regarding the *saladas*, 50% of water comes from atmospheric precipitation, 40% from groundwater storage close to the lake surface, and 10% from surface runoff water. The main water inflows to Gallocanta Lake come from groundwater. Evapotranspiration is the only water outflow of the four lakes [45]. Lakes Salineta (C) and Pito (D) are located 1 and 6 km south of Bujaraloz village (Zaragoza province, 1013 inhab.), respectively. Due to the high salinity and the salt crust formed during the frequent desiccation periods, these lakes were used as natural sources of salt until the 1950s [45]. Sariñena Lake (A) is very close to Sariñena village (Zaragoza province, 4164 inhab.). Gallocanta Lake (B) is surrounded by 5 small villages (Gallocanta 120 inhab., Berrueco 32 inhab., Tornos 196 inhab., Las Cuerlas 39 inhab., and Bello 230 inhab. [46]) and located between the provinces of Zaragoza and Teruel.

2.2. Sampling in the Field

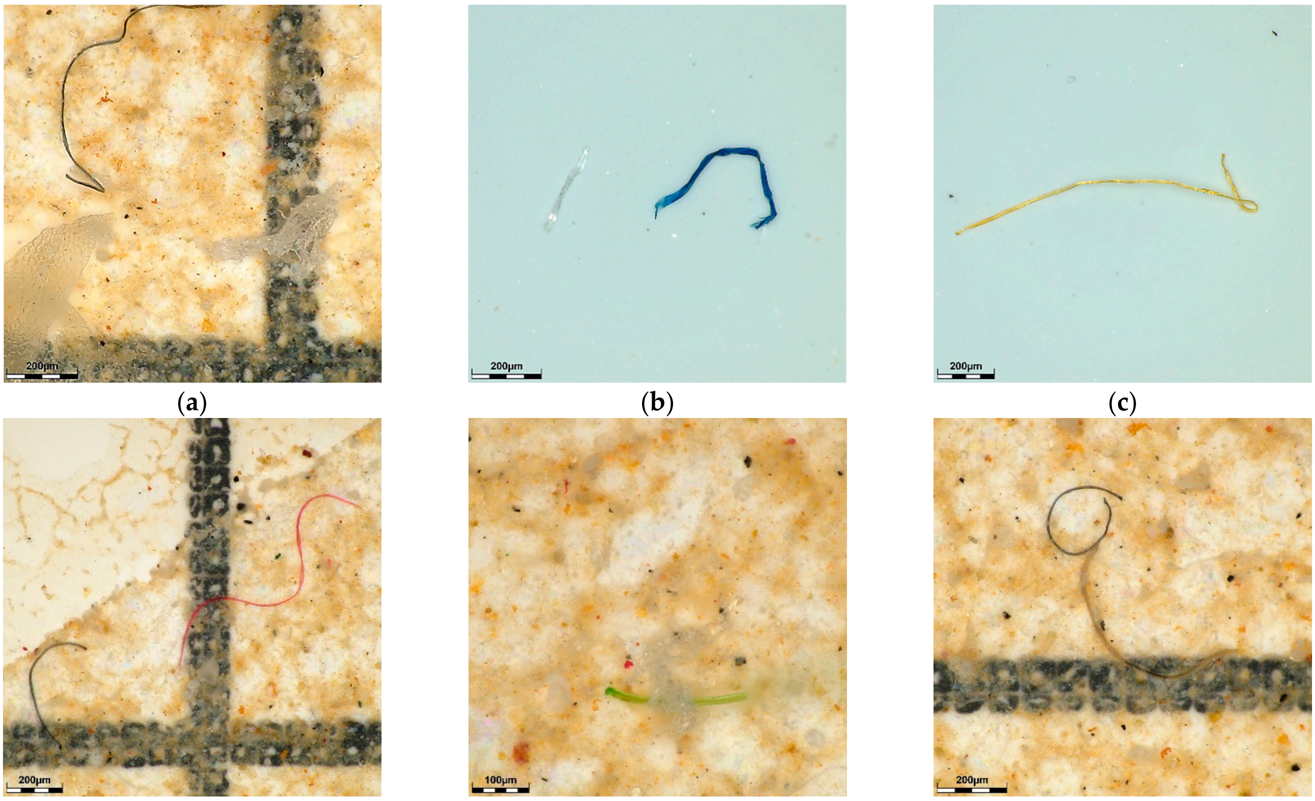
Samples were obtained a few meters from the shore at a depth of 20 cm, avoiding areas of natural accumulation of debris (due to water currents and/or wind) and trying to avoid uplifting sediments. For that purpose, a few seconds were allowed between entering the water and taking the sample, letting particles settle. Sampling was conducted using a hard PET 500 mL bucket, with 250 mL glass jars filled with metal lids. Three replicas were obtained from each sampling point. Only glassware was employed in the laboratory, and glass jars were previously cleaned with ultrapure water to avoid cross-contamination before sampling. Salinity, pH, and electrical conductivity of the water were recorded, as well as weather conditions of the sampling day, plus any other field observations deemed relevant, in order to help interpret potential anomalies (e.g., windy or hot days that may affect plastic availability). Sampling was performed in December 2022 on a sunny day with a light-gentle breeze (7–13 km/h, 2–3 on the Beaufort scale) and a relative humidity ranging between 65 and 93%. Once in the laboratory, samples were stored in a dark place to prevent light from altering MPs present in them.

2.3. Materials and Sample Preparation

All containers and tools used were rinsed with ultrapure water three times to avoid contamination. Cotton laboratory coats were worn, and nitrile gloves were always used. 50 mL of each water sample were treated with 10 mL of hydrogen peroxide (H_2O_2) 30% v/v (Merck, Darmstadt, Germany) in 1 L glass bottles to remove any organic matter present in the sample. The bottles were adequately sealed and placed into an oven at 65 °C for 24 h to degrade organic matter. After digestion, all the liquid was filtered through 5 µm gridded cellulose nitrate filters (Sartorius Stedim Biotech GmbH, Göttingen, Germany) using a vacuum system. Once filtration was finished, all filters were placed into Petri dishes and stored in darkness. Three 1 L glass bottles were used as a blank, with 10 mL of H_2O_2 30% v/v and 50 mL of ultrapure water, to control possible contamination during laboratory procedures.

2.4. Analytical Procedure

Optical MP counting and measurement were performed with a DSX1000 microscope (OLYMPUS®, Tokyo, Japan). Microphotographs were analyzed using the IC Measure® software (Version 1.1.2.9, 2019 OLYMPUS CORPORATION). MPs were classified according to color and size. Different colors observed were black, blue, brown, green, red, yellow, and transparent. Size ranges were: 5–100 µm, 100–250 µm, 250–500 µm, 500–1000 µm, 1000–2500 µm, and 2500–5000 µm. MP microphotographs of different morphologies and colors are shown in Figure 2.



(**a**) (**b**) (**c**)

(**d**) (**e**) (**f**)

Figure 2. Microphotographs obtained by the DSX1000 microscope OLYMPUS®: (**a**) transparent fragment and black fiber; (**b**) transparent and blue fibers; (**c**) yellow fiber; (**d**) black and red fibers; (**e**) green fiber; (**f**) black and brown fibers.

Polymer identification of the MPs was performed by micro-Fourier Transform Infrared Spectroscopy (micro-FTIR) using a Jasco IRT-5200 Infrared Microscope (JASCO ANALITICA SPAIN, Madrid, Spain) with a 16× Cassegrain lens and MCT detector, coupled with a JASCO FT/IR-4700. The equipment operated in transmission mode with a spectral range of 4000–700 cm^{-1}, 8 cm^{-1} resolution, and 100 scans. The aperture size was adapted according to the size of the MPs, being the minimum aperture of 10 × 10 µm. The background interference was measured against air on the filter with the same settings prior to each analysis. MP particles were analyzed in different randomly selected squares of the gridded filter, which accounted for 30% of the total filtered area.

The Advanced Spectra Search (ADSS) software® (Spectra Maganer Version 2.2.0.7, 2017–2020 JASCO Corporation) together with its MP library provided by Japan Spectroscopic Company (JASCO, Tokyo, Japan), were used in the identification of polymer type. Following Liu et al. [47], a minimum percentage of 60% was selected to match the sample and the library spectrum. FTIR spectra for some of the MPs found in these four lakes are shown in Figure S1 (Supplementary Materials).

3. Results

3.1. Presence of MPs

The presence of MPs in the four saline lakes is presented in Table 2 as concentration (MPs per liter). The concentration of MPs in these lakes varies from 850 ± 271 to 1556 ± 59 MPs per liter (mean ± standard deviation, SD). A relatively homogeneous abundance of MPs can be observed in lakes A and B and in lakes C and D, the latter presenting a higher concentration. Regarding the typology, most of the MPs were fibers, over 98%, with a very low presence of fragments, lower than 2%. MP concentration observed in these lakes is higher than those reported in previous works [24,38,41,42,48].

Table 2. The concentration of MPs per liter (± SD) and typology of MPs (%).

ID	MPs/L	Typology (%)
A	916 ± 518	Fiber (100%)
B	850 ± 271	Fiber (100%)
C	1486 ± 100	Fiber (100%)
D	1556 ± 59	Fiber (98.4%); fragment (1.6%)

The studied saline lakes are endorheic and thus terminal basins and suffer from irregular and long drought cycles, so pollutants can accumulate during the filling and evaporation cycles of the lakes and never outflow the basin. Given the ephemeral nature of the lakes, the aeolian dispersal of MPs retained on the surface of sediments may also be a contributing factor. This effect can be especially observed in lakes C and D, which are significantly smaller than lakes A and B and show a higher presence of MPs. Besides this, these lakes are surrounded by farmland and industrial activities, and lakes C and D are also located in closed depressions delimited by escarpments. Also, the size of the filter, smaller than filters used elsewhere, contributes to retaining more MPs

3.2. Polymer Type Characterization

Figure 3 presents the results of the size distribution of the MPs in the 5–5000 µm range. Sampling results only show MPs with possible anthropogenic origin, and microparticles with natural origin, either organic or mineral, have not been analyzed. Most of the MPs collected are contained in the 250–500 µm range (over 27%), except for lake B with a larger size distribution (500–1000 µm, 42%). The smallest range (5–100 µm) has been only found in lakes C and D, and MPs larger than 2500 µm were not found in lake A. The smallest lakes, C and D, show a more homogeneous size distribution than lakes A and B. Lakes C and D are temporary, located in an open area with very frequent and strong winds, and close to the industrial activities of Bujaraloz village, specifically next to a plastic tank factory and an alfalfa drying plant. These factors can influence the high MP concentration. In addition, both lakes were used for harvesting salt till the 1950s, affecting the morphology of original aeolian deposits and halophytes distribution that are much better preserved in other non-exploited playa-lakes in the area.

Figure 4 shows the color distribution of the MPs present in the four lakes, Figure 5 represents the polymer distribution of MPs, and Table 3 summarizes the polymer distribution according to each color. Seven different colors were observed, namely black, blue, brown, green, red, transparent, and yellow. Regarding the polymer composition, seven different types were found, namely polyester, polypropylene (PP), polyethylene terephthalate (PET), polyacrylonitrile (PA), nylon, styrene/butadiene copolymer (STY/BUT), and polyvinyl chloride (PVC). As can be seen, black MPs were the most abundant ones, followed by red, transparent, and blue. Brown MPs were only found in Lake C, green MPs in Lake A, and yellow MPs in Lake D. Most common polymers found were polyester, PET, and nylon. PA and PP fibers were also found in lakes C and D with a representative percentage (C: 14.2% PA and 13.7% PP; D: 23.7% PA and 5.9% PP). Polyester and nylon MPs were found in the four lakes, and PET MPs in lakes B, C, and D. STY/BUT and PVC polymers were only found in lake D. The smallest lakes, C and D, presented the highest MP variety in color and polymer composition. Cellulose, linen, and cotton microparticles were also obtained in the four lakes, the last two with a very low representation. Although fibers are of natural origin, they can also be synthetically produced and positioned between natural and artificial fibers [49–51]. In this work, as the location of the studied saline lakes is in flat, open, and windy areas surrounded by dryland and irrigated cereal, and most of these fibers were not dyed (they were transparent), we did not include cellulose, linen, and cotton microparticles in the results.

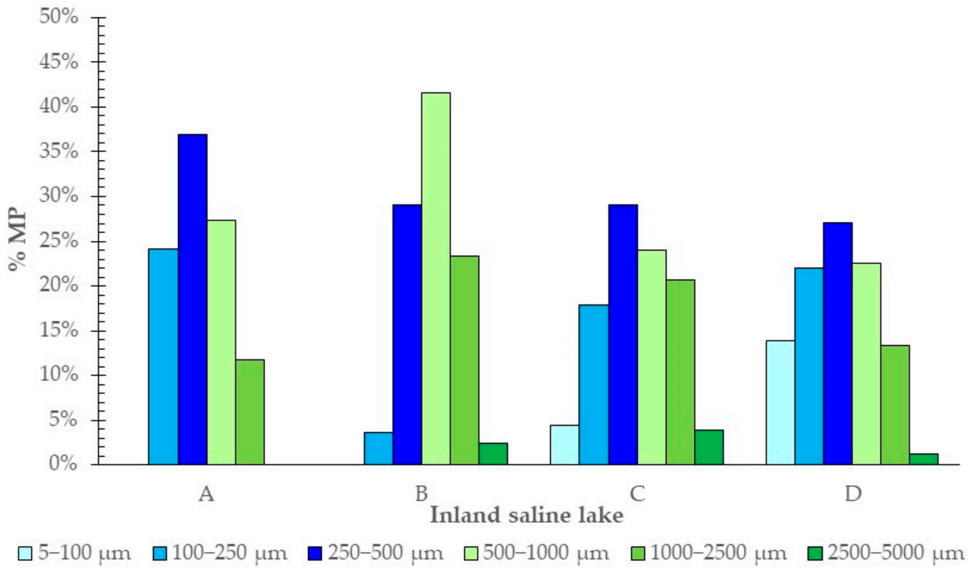


Figure 3. Size distribution (%) for MPs identified in all samples.

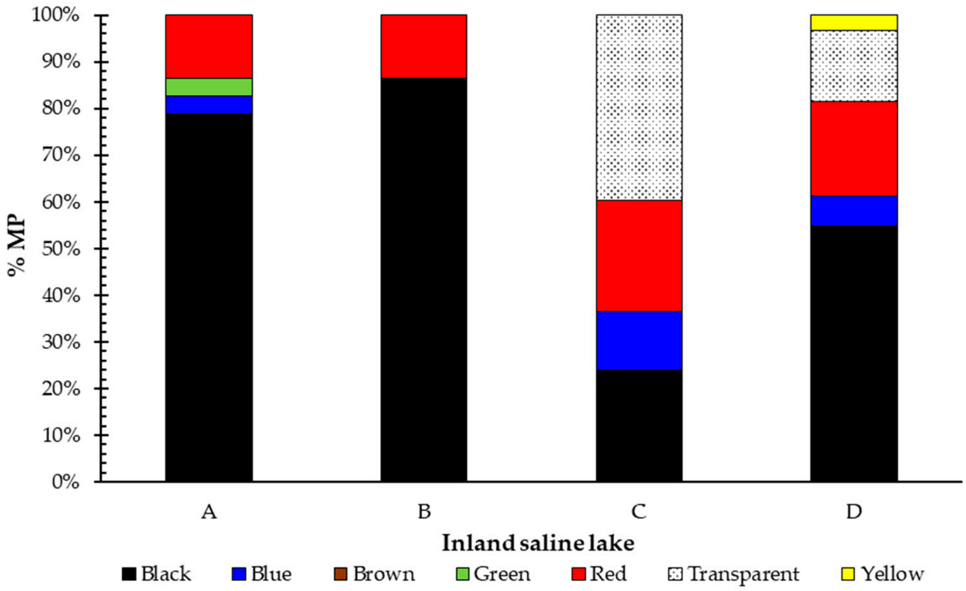


Figure 4. Color distribution (%) for MPs identified in all samples.

As can be observed in Table 3, polyester has shown a great variety of colors, followed by PET and PA. Black and blue MPs are mainly made of polyester and PET (black: 66.7% polyester and 24.8% PET; blue: 49.6% polyester and 41.5% PET), and red and transparent MPs of polyester (45.4% and 42.4%, respectively).

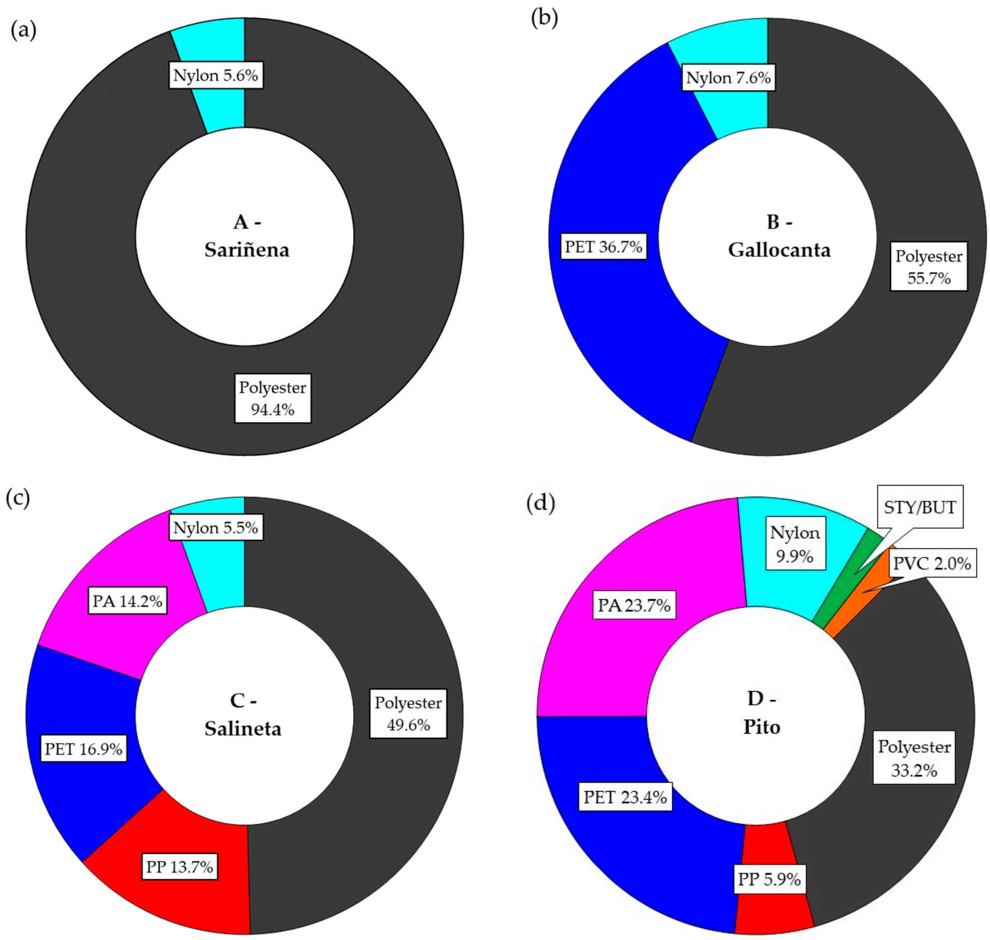


Figure 5. Polymer distribution (%) for MPs identified in all samples: (**a**) Sariñena lake; (**b**) Gallocanta lake; (**c**) Salineta lake; (**d**) Pito lake. (PET: polyethylene terephthalate; PA: polyacrylonitrile; PP: polypropylene; STY/BUT: styrene/butadiene copolymer; PVC: polyvinyl chloride).

Table 3. Polymer distribution (%) according to MP color.

	Black	**Blue**	**Brown**	**Green**	**Red**	**Transparent**	**Yellow**
Polyester	66.7%	49.6%	100.0%	100.0%	45.4%	42.4%	-
PP [1]	-	8.9%	-	-	-	16.4%	-
PET [2]	24.8%	41.5%	-	-	13.1%	13.2%	-
PA [3]	5.6%	-	-	-	20.9%	15.5%	100.0%
Nylon	1.5%	-	-	-	16.2%	12.6%	-
STY/BUT [4]	1.4%	-	-	-	-	-	-
PVC [5]	-	-	-	-	4.4%	-	-
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

[1] Polypropylene. [2] Polyethylene terephthalate. [3] Polyacrylonitrile. [4] Styrene/butadiene copolymer. [5] Polyvinyl chloride.

4. Discussion

Along with this work, the study of water samples from a diversity of inland saline lakes covering locations from the three provinces (Huesca, Zaragoza, and Teruel) has allowed us to gather information about the presence and nature of MPs in their waters. Consequently, it has been possible to infer some of the causes and mechanisms explaining these results. Consistent with the above, the obtained results are perfectly comparable with those available in the literature. In this way, it has been reported that in Lake Maharloo [42], the most abundant polymer types were PET, PE, and nylon. The atmosphere is, by at least an order of magnitude, the most important source of MPs. In the Mancha Húmeda wetlands, the most abundant plastics were polyolefins, PE, PP, polyester, and acrylic fibers [31]. Similar findings were reported by Liu et al. [39], Alirezazadeh et al. [24], and Zhang et al. [41].

As mentioned earlier, a significant percentage of the fibers found in this study are due to cellulose. The lakes, located in open and steppe areas, are surrounded by dry, farmed, and irrigated cereal. Although the origin of the cellulose is unknown, the fibers may result from the aeolian dispersal of dry plant matter. The significance of this result lies in the fact that for those cellulose fibers of anthropogenic origin, usually detected by their color, care should be taken in considering the potential toxicity of the dyes [17]. In our work, we focused on artificial polymers, and we did not consider colored cellulose fibers (linen or cotton) in the results, as the toxicity of the dyes is not within the scope of this research.

A relevant aspect revealed by the analyses carried out is the fact that MP concentration in these four saline lakes in the CEB is much higher than the values previously reported in different lakes around the world. Alfonso et al. [38] obtained an MP concentration of 0.1433 ± 0.0404 MPs/L in La Salada Lake in Argentina, Abbasi and Turner [42] and Alirezazadeh et al. [24] reported concentrations from 2 to 34.3 MPs/L in hypersaline Maharloo lake in southwest Iran, Liang et al. [48] a concentration ranging from 0.5 to 5.56 items/L in a remote saline lake on the Tibetan Plateau in China, and Zhang et al. [41] a content of 1.8 and 10.1 MPs/L in Qinghai–Tibet Plateau and Yunnan-Guizhou Plateau lakes, respectively. Our results show that MP concentration in the *saladas* of Bujaraloz-Sástago and Gallocanta Lake is at least one (and even two) orders of magnitude higher than the previous values reported.

Not only the location and size of saline lakes but also their geological features, wind-related processes, and landforms must be taken into consideration in order to explain the results. Thus, being endorheic basins, pollutants accumulate during the filling and evaporation cycles of the lakes, never outflowing the basin. The effect of MPs in endorheic basins should, therefore, be studied, as it is expected to multiply fast as the particles accumulate in sediments and biota (e.g., fishes in Sariñena Lake). This is especially visible in the Salineta and Pito lakes, which are significantly smaller than the Gallocanta and Sariñena lakes, resulting in a more homogeneous MP type and size distribution, together with the fact that they also suffer from more irregular and longer drought cycles. Particularly, Gallocanta Lake is a large lake also with outstanding wind activity affecting the water and sediments [15], while Sariñena is now a permanent lake due to the alteration of its fluctuating character after decades of irrigation return flows. Salineta and Pito are found in closed depressions delimited by escarpments and located close to industrial and intensive farm activities, thereby facilitating the accumulation of plastic debris and MP fallout. This could explain the higher diversity of plastic types and colors found in these lakes.

The four lakes studied are surrounded by farmland that often reaches the very edge of the wetland, as can be seen in Figure 1. Most of it is dry-farmed cereal except in Sariñena, which is under irrigation. Plastic greenhouses exist in San Juan de Flumen, a town located 3 km southwest of Sariñena [52]. Besides the increasing industrial activity in these areas, including intensive farming and animal feed factories, according to a previous study [53], plastic greenhouses are growing across the region. These different variables need to be considered as part of a multifactor system to give a broad and complete explanation of the aforementioned causes.

In addition, atmospheric deposition of MPs has been shown in different conditions. A comparison of snow in remote areas, such as the Arctic and urban areas, has shown that, although urban snow had a significantly higher concentration of MPs, these were also found in Arctic snow [54]. Rain has also been shown to be a deposition mechanism for MPs [42,55]. Atmospheric fallout of MPs has also been proven in inland *salinas* in Spain, located in isolated regions with similar topographic and climatic conditions as the wetlands studied here [30]. The presence of MPs in saline wetlands in a region (Gallocanta Lake) that features one of the lowest population densities in Europe further hints at its atmospheric origin. According to Xiao et al. [56], MPs with a fiber-like morphology present a lower density, high resistance, and slower sedimentation rate, which contributes to remaining suspended and being air transported over long distances. Furthermore, the influence of other factors, such as wind and derived water current regimes [15] and the role of vegetation, especially the annual concentration of thousands of migratory birds capturing and spreading MPs, should not be forgotten. The role of the wind is also important to understand the accumulation of plastics in certain parts of the basins, which may enter the sediments easily due to the frequent cycles of desiccation and inundation of the shores or even the whole lakebed when the lake completely desiccates. The shape of the bottom of the basins may, in turn, influence the flow of water, which, in combination with the wind, may facilitate accumulation in certain parts of the basin. This is especially relevant in lakes with windward barriers, longshore currents, and coastal sedimentary forms that favor the accumulation and sedimentation processes that occur in Gallocanta Lake [15]. Shoreline vegetation may also contribute to trap microplastics and act as windshields [57]. Birds, on the other hand, also act as a dispersal factor. They are considered excellent bioindicators of MPs dispersal through their guts, thanks to their mobility [26]. Inland lakes in arid areas are preferred habitats such as stopovers, nesting, or wintering sites for migratory species, which may be in large numbers. As mentioned above, Gallocanta Lake, for instance, may host up to 20,000 common cranes (*Grus grus*) during the winter. Opportunistic species such as white storks (*Ciconia ciconia*) or black-headed gulls (*Chroicocephalus ridibundus*), common in the areas studied, have proven to carry MPs from polluted feeding grounds, such as landfills [25,58].

Intuition says that the older the plastic, the smaller the size of MPs (due to erosion and degradation), although size may also be determined by composition, exposure, and additives used, making it an unviable assumption. However, the determination of the age of the microplastics found would contribute to understanding the rate of accumulation and predict future trends in the amounts and types of plastic found in saline lakes. This is especially important for terminal, endorheic lakes, where there is no outflow. MPs can only abandon the lake by prior desiccation and aeolian transport. Knowing the age and type of plastic waste may also help understand the toxicity of the additives and other substances used in the manufacturing of those plastics [59] and predict the consequences of their presence in these fragile ecosystems, which are very vulnerable to environmental changes. Hence, understanding the MP accumulation dynamics is essential to obtain reliable data on their presence, evolution, and fate.

Justification of Sample Size and Future Research Directions

This study represents an initial assessment of MP presence in saline lakes of the CEB. The selection of sampling sites was based on the diversity of geomorphological characteristics of the studied lakes and their accessibility and representativeness within the CEB. However, logistical and climatic constraints limited the number of samples collected in this preliminary phase. Despite this, the results provide valuable insights into MP pollution in these endorheic environments.

Given that saline lakes act as natural sinks for contaminants, it is crucial to expand this research in future studies. Given the shallow and ephemeral nature of most lakes in the region, further investigations will focus on analyzing MPs in sediments to assess their long-term accumulation and potential impact on associated biota. These complementary studies will provide a more comprehensive understanding of the distribution and fate of MPs in these fragile ecosystems.

5. Conclusions

This study examines water samples from saline lakes across three provinces in the CEB (Huesca, Zaragoza, and Teruel) in order to investigate the presence and nature of MPs. Results are consistent with prior work in the literature, showing similar MP size distributions and types, with polyester, PET, and nylon being the most commonly found polymers. However, some particularities have been observed in these lakes due to their special geological and climate characteristics.

Particularly, the presence of cellulose fibers, likely dispersed by wind, needs to be commented on due to their high concentrations, which may come from anthropogenic sources, raising concerns about the toxicity of dyes in these fibers. A key finding is that the MP concentration in the *saladas* of Bujaraloz-Sástago and Gallocanta Lake, ranging from 850 ± 271 to 1556 ± 59 MPs/L, is much higher than in other saline lakes, at least one order of magnitude compared to previous values reported.

Even though atmospheric deposition is a significant source of MPs in these areas, other different causes should be considered. One crucial factor is the endorheic nature of these lakes, causing pollutants to accumulate during cycles of filling and evaporation and, therefore, resulting in high MP concentration. Thus, smaller lakes affected by longer drought cycles and featuring steeper slopes, like Salineta and Pito, are more strongly affected by faster MP accumulation due to their geological features, longer drought cycles, and nearby anthropic activities. Apart from atmospheric deposition and water inflow regimes, other factors, such as agricultural, industrial, and farming activities, including plastic greenhouses near these lakes, contribute to MP contamination of water in the inland saline lakes. Vegetation and wildlife, particularly migratory birds, must also be considered in the study of MP dispersion.

Understanding the dynamics of MP accumulation is critical, with special attention to endorheic lakes where plastics degrade over time and remain trapped without outflow. This study highlights the need to determine the distribution of MPs to better predict their environmental impact and the potential toxicity of plastic additives in particularly fragile ecosystems, such as saline lakes.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/w17070989/s1, Figure S1: FT/IR spectra for MPs detected: (a) cellulose; (b) linen; (c) polyester; (d) polypropylene (PP); (e) polyethylene terephthalate (PET); (f), polyacrylonitrile (PA); (g), nylon; (h), styrene/butadiene copolymer (STY/BUT); (i), polyvinyl chloride (PVC); (j), wool. Gray zones are the vibrational bands of cellulose nitrate from filters.

Author Contributions: K.H.-K.: Conceptualization, Formal analysis, Methodology, Resources, Writing—original draft, Writing—review and editing. N.D.-M.: Data curation, Methodology, Investigation, Validation, Visualization, Writing—original draft, Writing—review and editing. J.C.-F.: Methodology, Investigation, Validation, Visualization, Writing—original draft, Writing—review and editing. C.S.-M.: Investigation. C.C.: Resources, Writing—review and editing. M.d.M.C.-C.: Conceptualization, Funding acquisition, Methodology, Resources, Supervision, Writing—review and editing. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the Comillas Pontifical University through the *Proyecto Propio* "*Microplásticos en Salinas*" (PP2020_01). This research was made possible by the grant PID2021-127170OB-I00 funded by MCIN/AEI/10.13039/501100011033 and by "ERDF A way of making Europe", and the grant TED2021-130303B-I00 funded by MCIN/AEI/10.13039/501100011033 and by the "European Union NextGenerationEU/PRTR".

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors upon request.

Acknowledgments: The analysis of some samples in the laboratory with the microscope has counted with the valuable contribution of Patrick Ting and Thomas Gonzalez, students at Johns Hopkins University (Baltimore, MD, USA).

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study, in the collection, analyses, or interpretation of data, in the writing of the manuscript, or in the decision to publish the results.

Abbreviations

The following abbreviations are used in this manuscript:

MP	Microplastic
CEB	Central Ebro Basin
FTIR	Fourier Transform Infrared Spectroscopy
NUTS	Nomenclature of territorial units for statistics
UV	Ultraviolet
PP	Polypropylene
PE	Polyethylene
PET	Polyethylene terephthalate
PA	Polyacrylonitrile
STY/BUT	Styrene/butadiene copolymer
PVC	Polyvinyl chloride

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